## 3.3.4 Landslide

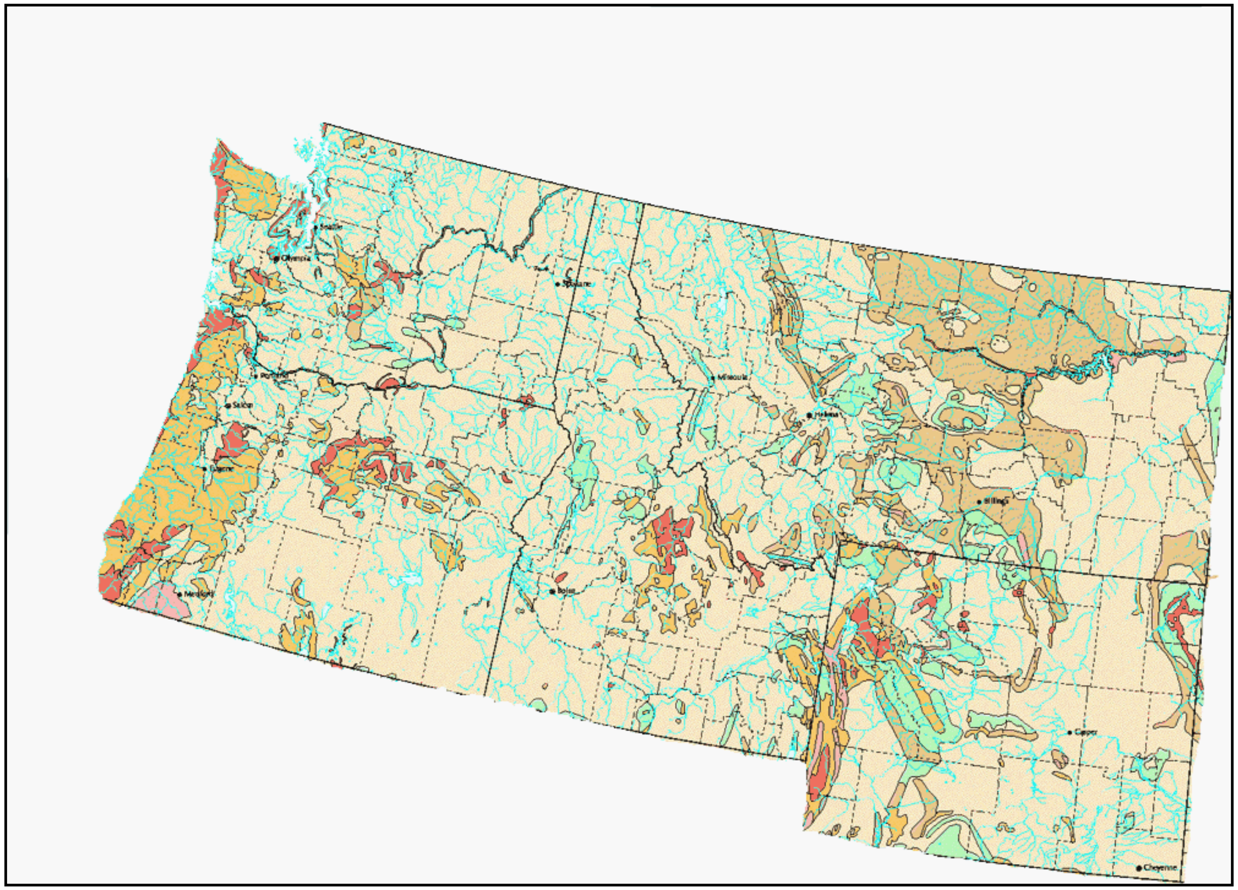
The term ***landslide***, as used here, includes all types of gravity-caused mass movements of earth material, ranging from rock falls, slumps, rock slides, mud slides, and debris flows. Landslides occur in all 50 of the United States (USGS, 2001a).

### 3.3.4.1 Background

- The surface of the Earth is a collection of slopes that are inherently unstable. When material is exposed at the Earth's surface, weathering and erosional processes immediately begin to break it apart and move it.
- Earth movement may occur suddenly as catastrophic landslides or rockfalls, but more commonly, occurs almost imperceptibly as the slow creep of soil down gentle slopes.
- Precipitation, topography, geology, and human activities can all trigger landslides.
- In landslide-prone areas, anything affecting slope condition, such as construction, seismic activity, or increased soil moisture, may cause movement or may reactivate prior movement.
- Recent landslide movements often are the reactivation of smaller sections of older, unstable landslide masses.
- Slope failures are often triggered by human activities, including mining and construction of highways, buildings and railroads.
- Landslides can damage and destroy homes, roads, railroads, pipelines, electrical and telephone lines, mines, oil wells, commercial buildings, canals, sewers, bridges, dams, airports, forests, parks, and farms.
- According to FEMA (1997), best estimates of losses attributed to landslides in the United States are 25 to 50 lives per year and **$1-2 billion** in property damage.

Source: USGS, 2004b; MBMG, 2002.

**Figure 3.3.4-1 Landslide Areas in the Northwest United States**. (Godt, 1997)



**LANDSLIDE INCIDENCE**

- Low (less than 1.5% of area involved)
- Moderate (1.5%-15% of area involved)
- High (greater than 15% of area involved)

**LANDSLIDE SUSCEPTIBILITY/INCIDENCE**

- Moderate susceptibility/low incidence
- High susceptibility/low incidence
- High susceptibility/moderate incidence

Note: Susceptibility not indicated where same or lower than incidence. Susceptibility to landsliding was defined as the probable degree of response of the areal rocks and soils to natural or artificial cutting or loading of slopes, or to anomalously high precipitation. High, moderate, and low susceptibility are delimited by the same percentages used in classifying the incidence of landsliding. Some generalization was necessary at this scale, and several small areas of high incidence and susceptibility were slightly exaggerated. (Godt, 1997)

### 3.3.4.2 History of Landslides in Montana

Landslides are among the most common geologic hazards in Montana, causing damage in rural and urban areas of the state. Sudden movements are often spectacular and receive much publicity. The Hebgen Lake Earthquake of August 18, 1959 triggered the **largest landslide in Montana history**, where nearly 1.25 miles (2 km) of the Madison River and Montana Highway 287 were buried to depths as great as 394 feet (120 m) (see **Section 3.3.1.2, History of Earthquakes**). However, slower movement can also cause severe problems in developing areas. The effects of the very slow (imperceptible) movements can be seen along many Montana roadways in the form of leaning trees, misaligned fences and walls, and damaged road surfaces and foundations (MBMG, 2002).

**Photo 3.4-1 Landslide from Hebgen Lake Earthquake, August 1959.**

Whether caused solely by natural processes or aggravated by human activity, when landslides occur in proximity to human-made structures, repairs and remediation can be costly. For example, a small lobe of a much larger ancient slide south of Dillon was reactivated by removing the toe of the slope. The slide is proving very costly to the railroad and could impact Interstate 15 if a larger segment of the slide area should move (MBMG, 2002). State Highway 2 was built on another slide near Glacier Park and the roadway has had constant subsidence problems. The Goat Lick slide forced the Montana Department of Transportation (MDT) to re-construct the roadway with a cantilevered outside driving lane to prevent further subsidence.

**Photo 3.4-2 Goat Lick Slide, US Highway 2.**

In Montana, or the nation for that matter, a readily available inventory of landslides and their impacts does not exist. The Montana Bureau of Mines and Geology (MBMG) initially began a statewide compilation of landslide information as part of a hazard assessment project in 1985 and 1986 in cooperation with the U.S. Geological Survey. However, the project was left incomplete and the data unpublished because federal funding for the hazard-assessment program was discontinued. MBMG and MDT did complete an inventory of landslides in the southwestern portion of Montana (MBMG, 2002), however, this inventory identifies priority areas based upon the susceptibility to landslides near state highways.

MBMG mapped 4,640 landslides within MDT's District 2, which were categorized as earth landslides (1,922 or 41.5 percent), debris landslides (2,556 or 55 percent), and rock landslides (162 or 3.5 percent). The most important movement types identified were slides (2,759 or 59.5 percent), followed by flows (1,813 or 39 percent), and composite or compound movement types (54 or 1.2 percent).

MBMG (2002) assigned a priority rating to each area containing clusters or large numbers of landslides (**Figure 3.3.4-2**). They determined that all of District 2 has clustered landslide areas, however, the Ennis 1:100,000-scale quadrangle area is considered overall to have the highest priority.

Landslides appear to have a stronger association with faulting than with any specific geologic unit (MBMG, 2002); however, some geologic formations or lithologies could be identified as being particularly prone to movement:

- Volcanic rocks, or sediments derived from them, are often the originating lithology for landslides. These sediments often contain ash and clay materials that facilitate movement.
- Poorly-consolidated sediments, particularly those of Cretaceous, Tertiary and Quaternary age, appear to have a tendency toward landsliding.
- In the Butte and Dillon 1:250,000-scale areas, Proterozoic-age (Precambrian Belt Supergroup) rocks appear to be prone to landsliding.

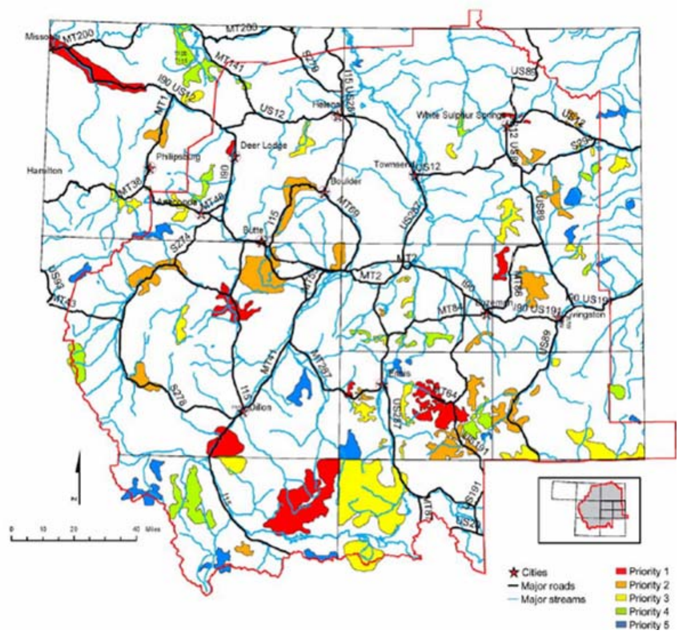



**Figure 3.3.4-2 Priority areas in District 2.** Source: MBMG, 2002**.**

The types of material identified for each slide or flow appears to generally correspond to well-defined topographic settings:

- Earth slides and flows occur most often on more gentle slopes with less vegetation—the foothills and river courses.
- Debris slides and flows generally occur in the steeper, mountainous areas and in areas covered with vegetation.
- Rock slides and flows occur in previously-glaciated high valleys with steep slopes that generally lack vegetative cover, and along other very steep slopes (generally greater than 50 degrees).

### 3.3.4.3 Declared Disasters from Landslides

No state or federal disaster declarations have been made since 1974 as the result of a landslide.

### 3.3.4.4 Vulnerability to Landslides

#### *3.3.4.4.1 Statewide Vulnerability to Landslides*

Vulnerability to landslides is dependent on slope, lithology, and location of current and ancient slides. Activation of landslides depends upon environmental factors, such as amount of rainfall and snowmelt, and human activities, such as road and housing construction.

A comprehensive map of existing slide areas throughout the state would greatly improve the capability to prevent development in ancient slides areas, however, many landslides cannot be predicted and can be activated by multiple factors including earthquakes, high precipitation, overgrazing, and deforestation (especially from forest fires). In Montana, as urbanization and development increase, particularly in the mountainous regions, the potential for large losses from landslides also increases. Landslide risk should be evaluated on a case-by-case basis to reduce or eliminate exposure of public infrastructure and private development.

Many, if not most, high-risk areas can be identified on the basis of past landslide activity. Many recent landslides are small, relatively minor events within the boundaries of older, much larger ones. Recognition of the larger framework, as well as mapping current landslide locations, is paramount to understanding the problem.

#### *3.3.4.4.2 Review of Potential Losses in Local PDM Plans*

Of the 6 counties that have completed Pre-Disaster Mitigation Plans, only 3 identified landslides as a hazard:

- Broadwater County determined a portion of the county is included within a landslide incidence area with publicly owned structures (Radersburg Fire Station and Waste Transfer Station) also within that general area. The county has concluded that the risk of loss to structures is very small and ranked the hazard with a low probability and magnitude.
- Butte-Silver Bow County identified landslides as a risk, but could not assign specific vulnerabilities due to the insufficient record of landslides and their associated losses.
- Yellowstone County had landslides impact roadways in 1978 and 1997. The county identified the Billings Rimrocks and the banks of the Yellowstone River as having the highest potential for landslide incidence. The county did not quantify potential losses from landslides.

#### *3.3.4.4.3 Vulnerability of State Property*

The ability to assess losses to state-owned buildings and infrastructure are dependent on the ability to map hazard areas and the ability to locate these structure and infrastructures within those zones. Montana does not have comprehensive and reliable landslide incidence mapping completed statewide and the state buildings cannot be geo-referenced. A second approach is to review historic losses and project those losses into the future. Over the past ten years, no insurance claims related to landslide damage have been made for state-owned buildings.

The greatest exposure to state infrastructure may be to roadways. Two of the major slides, the Pipe Organ slide on Interstate 15 and the Goat Lick slide on Highway 2, were discussed previously. Both slides that bury public roads, and those that undermine them, represent significant costs to the state. Although historically, damages to public roads from landslides have occurred, the Montana Department of Transportation does not maintain a compilation of losses and repairs to roadways as a result of landslides.

The potential losses from landslides to state buildings and infrastructure cannot be estimated quantitatively without detailed mapping. Qualitatively, however, without past disaster declarations from landslides, the impact can be considered low.

### 3.3.4.5 Landslide Data Limitations

The major data limitation regarding landslides is the lack of statewide information on existing landslides and landslide-prone areas. The USDA Forest Service has mapped landslide areas on individual National Forests, but this information is not digitally available.

***Limitations to State Building Evaluations***
To effectively determine vulnerability of State property, data identifying locations of State buildings is necessary. The current PCIIS building database is not geo-referenced and cannot be effectively related to spatial coordinates except in general locations (by city or zip code centroid).

***Limitations to MBMG (2002) Study of MDT Region 2***
Any use made of the MBMG (2002) data regarding MDT Region 2 should consider the methods of collection and interpretation, and the scale at which the initial data were gathered:

- The original compilation of data was done at 1:250,000 scale; therefore, if the data are used at a larger scale, inaccuracies could occur in both location and shape.
- Locations were originally gathered using several methods: aerial-photo interpretation, literature references, aerial reconnaissance, and field mapping.
- Locations were checked by either fieldwork or aerial reconnaissance, but detailed mapping was not done in either case.
- Data have been provided by several investigators and at various scales, therefore inconsistency in definitions, recognition of types, and locations may exist. More detailed studies in specific areas may require corrections and/or additions to the database.
- The information, location, references, and definitions in the database and in this report are as complete as feasible at this time, but must be considered as products that will continue to evolve as new or improved data become available.
- The accuracy of the landslides located from aerial photographs varies according to date, quality, and scale of the photographs.

### 3.3.4.6 Landslide References

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